Jefferson Lab
Proposal Cover Sheet (Generic)

Experimental Hall: A
Days Requested for Approval: ____

Submission Date: 5/94
Other: PAC 8

☐ **New Proposal Title:**
☒ **Update Experiment Number:** 91-006
☐ **Letter-of-Intent Title:**
(Choose one)

Proposal Physics Goals
Indicate any experiments that have physics goals similar to those in your proposal.

Approved, Conditionally Approved, and/or Deferred Experiment(s) or proposals:

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By: ____

CEBAF EXPERIMENT 91-006
UPDATE

Study of Nuclear Medium Effects by Recoil Polarization up to High Momentum Transfers

The Hall A Collaboration
Spokesperson: *A. Saha*

The effect of the nuclear medium on the propagation of nucleons continues to be of fundamental importance in the investigation of the nuclear many body problem and its study continues to be of great relevance today. This proposal plans to make a systematic study of the nuclear medium effects by measuring the Q^2 and A variation of both the cross sections and polarization variables in the *(e,e'p)* reaction in Hall A.

As one goes to higher values of Q^2, one hopes to see the effects of "color transparency" as predicted by Brodsky and Muller. Many models in the context of the parton model and PQCD have been proposed in the literature to describe the evolution of the hadronic cross section associated with the occurrence of color transparency. Experimental evidence of color transparency can also be inferred from *(e,e'p)* reactions at high momentum transfers by studying the A and Q^2 dependence of the nuclear absorption of the knocked out proton and this formed the motivation of the SLAC NE18 experiment. Color Transparency is expected to lead to a modification of the final state interaction (FSI) of the struck nucleon with respect to the prediction of the conventional picture in which the nucleons are assumed to be structureless.

In addition to measuring the *(e,e'p)* reaction cross sections, this proposal also plans to measure the recoil polarization of the ejected proton. The normal component of the polarization response function, P_n, provides a dual advantage in studying nuclear medium effects:

- Theoretically, its presence is only due to FSI and minimally affected by two-body currents. Hence it becomes a clean measure of FSI (it is zero to first order in PWIA due to time reversal symmetry) and consequently an excellent observable to measure the onset of color transparency, if it exists, in the CEBAF kinematic domain.
- It also happens to be the sole surviving polarization response function measured with an unpolarized beam and in coplanar kinematics. Experimentally, therefore, it is a clear signal to measure with the Focal Plane Polarimeter planned to be installed in the hadron arm.

This experiment therefore plans to study nuclear medium effects by measuring the Q^2 variation (1 to 6 $(GeV/c)^2$) of the cross sections and the normal component of the recoil polarization, P_n, in the *(e,e'p)* reaction on deuterium (^2H) and other nuclei (^4He, ^{12}C and ^{16}O) at essentially the same quasielastic kinematics for each nucleus with the pair of high resolution spectrometers in Hall A. The reaction will also be performed on the proton (^1H), where $P_n = 0$ at all momentum transfers due to absence of FSI.

The highlights of this experiment compared to those already performed or are being proposed to study nuclear medium effects and color transparency are:

- It requires a fixed beam energy of 4 GeV for all the Q^2 values and requires only an unpolarized beam. In the near future with a 6 GeV beam, the measurements could be extended to $Q^2 = 8$ $(GeV/c)^2$, provided one of the spectrometers can be configured to reach a momentum of 5 GeV/c.

- It spans a large Q^2 range (1 - 6 $(GeV/c)^2$), with the spectrometers remaining unchanged for proton and electron detection for all the Q^2 values.

- Full acceptance coverage in missing energy (e_m) and recoil momentum (p_R)for all values of Q^2 and A.
  $\underline{\Delta e_m \geq 300 \text{ MeV}}$. This will enable one to obtain the full single particle strength in each residual nuclei, *at each setting* of the spectrometers.
  $\underline{\Delta p_R \geq 300 \text{ MeV/c}}$. This will enable one to obtain nearly the full momentum distribution strength, *at each setting* of the spectrometers.
  The enclosed figure shows the phase space acceptance in (p_R - e_m) space for this experiment using the full Monte-Carlo calculation (code MCEEP) for the ^{4}He*(e,e'p)* reaction for $Q^2 = 1$, 3, and 6 $(GeV/c)^2$. One obtains basically the same coverage for all the other nuclei we plan to study. With unmatched spectrometers as in the other proposals, measurements have to be performed at several settings of the spectrometers, for each Q^2 value, to span the full missing momentum range. This is especially true at the lower Q^2 values, as was the case in the SLAC NE18 measurements, leading to additional uncertainties in the determination of the momentum distributions and additional beam time request.

- High resolution ($\underline{\delta e_m \cong 1 \text{ MeV}}$) for the full Δe_m acceptance for all values of Q^2 and A. This is good enough not only to separate the various shells but also to observe discrete states in the residual nucleus within each shell. The overall good resolution and vertex reconstruction capabilities of the two high resolution spectrometers (HRS^2) in Hall A are absolutely necessary to control systematic errors, especially if one wishes to see any effect at the 5 - 10% level.

- Finally, we shall measure <u>both</u> the cross sections and polarization variables for each nuclei to very high precision.

$\Delta\sigma \leq 2\%$	($\leq 1\%$ statistics)	for all Q^2 and A.
$\Delta P_n \leq 0.05$		for $Q^2 \leq 4$ (GeV/c)2.
$\Delta P_n \leq 0.1$		for $Q^2 = 5,6$ $(GeV/c)^2$.

Even though there are quite a few models and calculations existing in the literature to describe the evolution of the occurance of color transparency, only one theoretical group (to the knowledge of the authors) has attempted to describe the evolution of the *(e,e'p)* polarization variables as a function of Q^2. The calculations are still preliminary and the predictions of the polarization variables are still debatable since they are extremely sensitive to the combined effects of the spin-orbit coupling and the optical potential of the ejected proton, which varies in energy as one varies Q^2. Nevertheless, we believe that an accurate experimental measure of the cross sections and the polarization variables as one goes to higher values of Q^2 are interesting observables of nuclear medium effects, irrespective of the predictions of any particular theory or model in this region. Moreover, an enhancement in the experimental cross section and a simultaneous reduction in the polarization response, P_n, due to reduction in final state interactions, would unambiguously suggest the onset of color transparency in this kinematic domain. Unfortunately, it is generally accepted that the effects of color transparency are quite small in this region of Q^2 ($\leq$ 10 $(GeV/c)^2$) and it is therefore extremely important to do a more precise and accurate measurement than has been performed in the past or are currently being proposed elsewhere.

This experiment requires all the standard equipment planned for Hall A. The capabilities of the two high resolution spectrometers, the focal plane polarimeter in the hadron arm and all the other accompanying instrumentation are ideally suited for an accurate measurement of P_n and the accompanying cross section measurements. Since this proposal was approved to run, it has been adopted by the full Hall A collaboration as a Hall A Collaboration experiment.

The groups from Rutgers University and the College of William and Mary are actively involved in the construction and calibration of the focal plane polarimeter. There are several approved Hall A collaboration experiments which require the focal plane polarimeter, and there are plans to calibrate it for higher proton energies using the self-calibration technique proposed in Proposal PR89014 (Contact: C. Perdrisat) or through direct measurements in a hadron facility. We prefer that this experiment be performed following this calibration of the focal plane polarimeter to higher energies.

The Cal. State L.A. group has made substantial progress in the construction and testing of the cryogenic target, and it is expected to be available during the first year of the Hall A experimental program. In fact, all the cryogenic targets planned to be used in this experiment (^1H, ^2H, ^4He) do not require the highest luminosity design requirements of the cryotarget system (1 kW) and could in fact run at less than 200 W for ^1H and ^2H and less than 400 W for ^4He. The Italian group (INFN, Rome) have taken on the responsibility to design and construct a waterfall ^{16}O target system. They have successfully implemented this target system to run at Saclay and at NIKHEF.

Most of the proposed measurements can be done using the precision of the beam and magnetic spectrometers that the Hall A collaboration plans to achieve during the first year of operation of Hall A. In general this experiment incorporates many of the experimental requirements of most of the approved Hall A coincidence program using the focal plane polarimeter and we believe that it should be included in the first group of experiments to be performed in this series. Since the physics interest in this measurement is still current and exciting and eminently executable, we request that this proposal be given the highest possible rating.

$$e_m = (e - e') - T_p - T_R$$
$$\vec{p}_R = \vec{q} - \vec{p}$$

^{4}He $(e, e'p)$ g.s.

MCEEP (Monte Carlo) Simulation